MIGRATION, GENDER, AND HIV INCIDENCE IN RAKAI, UGANDA

by

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Abstract

Background: Higher HIV prevalence is commonly observed among migrant population in sub-Saharan Africa, however the extent to which migration is a cause or consequence of HIV infection is largely unknown. Here, we use population-based, longitudinal survey data and assess HIV incidence among men and women migrating into communities in Rakai District, Uganda.

Methodology: Prospective data from HIV-negative participants residing in thirty communities under continuous surveillance in the Rakai Community Cohort Study (RCCS) between 1999 and 2016 was used to assess the association between recent migration and HIV incidence. The RCCS is an open population-based census and cohort of adults aged 15-49 in rural southcentral Uganda. Recent in-migrants were classified as individuals who moved to a new community within the last two years with intention to stay and were identified through census. Newly HIV-positive individuals were considered incident HIV cases if they had an HIV negative test result at the prior survey allowing for one missed visit. Poisson regression with generalized estimating equations and robust variance estimators were used to estimate the incidence rate ratios (IRR) of HIV infection associated with recent migration for men and women visits with adjustment for demographics, sexual risk behaviors, and calendar time.

Results: The association between HIV incidence and recent migration was assessed among 16,165 HIV-negative individuals of which 55% (n=8,789) were women and 28% (n=4529) were classified as recent migrants. Participants contributed 69,231 person-visits at which 851 incident HIV events were identified (n=357 in men; n=492 in women). Compared to long-term residents, risk of HIV-infection was statistically significantly elevated among migrant women relative to long-term

residents before and after adjustment for potential confounders (IRR=2.10, 95%CI:1.62-2.73; adjIRR=1.81, 95%CI: 1.37-2.41). Similar risk of HIV with migration was found among men

(IRR=1.82, 95%CI: 1.17-2.86); adjIRR=1.80, 95%CI: 1.14-2.82). We found no significant differences in the association between migration and HIV by calendar time in our analyses.

Conclusion: Our Data suggests that the earliest years after migration is associated with increased risk of HIV acquisition in men and women. These findings highlight the need for timely interventions targeted to migrant population to reduce HIV incidence in sub-Saharan Africa.

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1. Introduction

In Sub-Saharan Africa, migrants have higher HIV prevalence than individuals with no migration history. However, the pathway through which migration is associated is not clear. Individuals who move may be more likely to be HIV positive or the migration process itself may increase HIV risk.

This thesis focuses on the of HIV infection following in-migration into 30 communities in rural Rakai, Uganda. Rakai, bordered by Lake Victoria to the East and Tanzania to the South, was the initial epicenter of the HIV epidemic in Eastern Africa.

Specifically, we use data collected between April 1999 and January 2016 from the Rakai Community Cohort study (RCCS) for this study. The RCCS is an ongoing longitudinal study of HIV incidence, sexual behaviors, and health service utilization in the Rakai District, Uganda. Here, we used RCCS census data to identify in-migrants and their time since arrival in RCCS study communities. We then compared HIV incidence between long-term residents with no migration history and in-migrants at varying times since in-migration to their new community.

1.1. Epidemiology of HIV/AIDS in Sub-Saharan Africa

More than 35 million people have died from AIDS related illness since the beginning of the epidemic more than thirty years ago.[1]Although progress has been made since the discovery of highly active antiretroviral therapy (ART) in 1996, the number of people living with the infection remains high.[1,2] In 2015, 2.1 million people were newly infected with the virus, bringing the number of people living with the infection globally to 36.7 million. Sub-Saharan Africa (SSA) bears a disproportionate burden of HIV cases. Although HIV prevalence has declined in some locations, the regions still accounts for 66% of people living with HIV and nearly 80% of AIDS-related deaths.[1,2]

Although HIV was first recognized amongst mobile and commercial sex workers in the Central and Eastern region,[3,4] the African epidemic is generalized affecting virtually all members

of the society.[5] The predominant mode of HIV transmission is through heterosexual sexual intercourse,[5] however men who have sex with men (MSM) and injection drug users (IDU) are increasingly being recognized as key populations at risk in the region.[6-8]

Adolescent girls and women are at highest risk of HIV acquisition in sub-Saharan Africa; women account for 52% of all people living with HIV in SSA.[1,9]Young women aged 15-24 are particularly at risk.[10] In some countries in SSA the prevalence of HIV in young women is two to eight times the prevalence in young men of the same age.[11,12] For example, a study carried out in Kenya and Zambia found prevalence was six and 3 times higher in sexually active 15-19-year-old and 20-24-year-old women respectively compared to sexually active men of the same age.[10,12]Reasons for gender disparities in HIV burden remain unclear however, biological differences in HIV transmission,[13] gender based violence, gender inequalities, poor access to education, reproductive, and sexual health services and poverty are presumed to be among the main drivers for increased female HIV risk observed in women in SSA.[1,9]

There are substantial heterogeneities in prevalence and risk factors for HIV throughout Sub-Saharan Africa. The countries in the southern and eastern region are the most affected with countries in Southern Africa having the greatest prevalence.[1,9] Swaziland, a country in Southern Africa has the highest burden of HIV in the world with a prevalence of 26.5%.[9,14] Lesotho and Botswana, also in the southern region of SSA have a prevalence of 23.1% and 23% respectively.[9,14] The burden of HIV in SSA is lowest in western countries where prevalence is estimated to be about 2%[5,9] with Nigeria being the most affected country in the region (3.1%).[9,14] Prevalence in the Eastern Africa is estimated to range from 2.9% to 7.9%.[9,14] The prevalence in Central Africa lies between levels in Eastern and Western Africa with estimates ranging from 1.1% in Democratic republic of The Congo to 3.1% Cameroon.[9,14]

1.2. Treatment and Prevention of HIV

Since the onset of the HIV epidemic, various treatment and prevention interventions have been put in place to limit the spread of the epidemic. Combined HIV prevention (CHP) strategies are being used to control the HIV epidemic.[15] CHP involves the implementation of multiple prevention interventions including antiretroviral therapy (ART), voluntary medical male circumcision (VMMC) and behavioral interventions to reduce HIV incidence.[15]

Antiretroviral therapy (ART) is the primary means for reducing HIV related mortality and is a key biomedical component of the CHP initiatives. Since ART was introduced in Sub-Saharan Africa in 2004 through the United States Presidents Emergency Plan for AIDS relief (PEPFAR) it has resulted in improved quality of life for persons living with HIV and substantial reduction in population-level HIV associated mortality.[16] While prior observational research strongly suggested ART reduced HIV transmission,[17-19] the role of ART in HIV prevention was demonstrated definitively in the landmark HPTN 052 randomized trial carried out in sero-discordant couples in 13 sites in Africa, Latin America, South Asia and North America.[20] Results from the trial demonstrated a 93% relative reduction in HIV transmission to the uninfected partner with early initiation of ART.[20]

Data from randomized control trials in the United States and Europe that daily pre-exposure prophylaxis (PreP) with oral ART also significantly reduces HIV acquisition.[21,22] PreP has been touted as pivotal for HIV prevention particularly in key populations where early HIV infection is an important driver of transmission (e.g. MSM) [23] and among persons who may be vulnerable to HIV infection (e.g. young women in SSA).[24] However, uncertainty about the population-level effectiveness of PreP remains particularly in sub-Saharan Africa, where low adherence to PreP regimens in clinical trials have resulted in significantly reduced efficacy compared to sites with high adherence elsewhere.[21,25]

ART is also effective for preventing mother to child transmission contributing to significant decline in pediatric infections in the SSA region. In the early 2000s with aid from the US government, countries in Sub-Saharan Africa started national programs which offered screening and treatment to HIV to pregnant women and their household.[26] In 2013, the World Health Organization (WHO) recommended option B+, the lifelong use of ART in pregnant and breast feeding women who are HIV positive regardless of their CD4 viral count.[15,26] ART therapy given to breast feeding mother and their infants have also been shown to reduce HIV transmission from an infected mother.[27]

VMMC is a cornerstone biomedical prevention intervention in CHP programs.[15]Pivotal randomized trial in Rakai, Uganda, Orange Farm in South Africa and Kisumu, Kenya showed approximately 50% reductions in HIV incidence in circumcised men compared to uncircumcised men with similar behavioral risk factors.[28-30] Medical male circumcision is particularly crucial in prevention strategies of settings of moderately high HIV prevalence with low circumcision rates.[15] Non-surgical male circumcision devices may be important in increasing the uptake of MMC. Several of these devices are undergoing regulatory assessments.[15]

In summary, ART and VMMC together with behavioral change interventions (e.g. testing, counselling and condom promotion) are the bedrock of HIV prevention in SSA.[15,31] Modelling studies have shown that concurrent use of these approaches could reverse the current epidemic, but only at high coverage levels.[15,32,33] Rapid and sustained decline in infection rates in SSA will require global investments to scale up testing, treatment and prevention programs.[16] Additionally, global and national commitment to ending the epidemic[34] through leadership, sustained local investments and partnerships, as well as policies that promote health seeking behaviors and human rights for those most at risk is needed in the regions most affected by HIV.[16]

1.3. HIV/AIDS in Uganda

Uganda, a country in Central East Africa, is considered one of the earliest epicenters of the HIV/AIDS epidemic in Sub-Saharan Africa.[4,35] The first cases of HIV in Eastern Africa were identified in a fishing village on Lake Victoria in Rakai District, Uganda in 1982.[4] It was originally referred to as "Slim" disease- due to the muscle wasting now associated with late stage HIV/AIDS infection.[4]

The HIV virus rapidly spread from the rural lake communities through trading routes to commercial centers and from there to rural inland communities. Initial prevalence in pregnant women peaked at ~ 30% in 1992 when it was estimated that 18% of the overall population was infected with HIV/AIDS and declined by 54% to a prevalence of 7.2% in 2012.[36] By 1995 approximately 90% of men and women in Uganda had known someone who died from AIDS.[36] Thus, the country initiated a comprehensive response to the epidemic including community based reporting of HIV-related deaths, mandatory education for men and women, prevention messages focused on abstinence, faithfulness in marriage and condom use with non-marital partners (ABC prevention).[34,36-38] By 2001 HIV prevalence had declined to significantly across age groups, particularly in the younger age groups,[36,37] however the main reasons for the decline observed has been subject to numerous debates.[36-39]

The modern HIV epidemic in Uganda is characterized by substantial variation in HIV burden by geography and demography, with higher infection rates observed among women, Lake Victoria fishing communities,[40] female sex workers and mobile populations.[41]For example, fisherfolk have a 42% HIV prevalence compared to a prevalence of 17% in trading communities and 14% in agrarian communities.[41] HIV incidence is also higher among fisherfolk, 6.04 per 100 person years in the fishing communities compared to 0.56 per 100 person years in the general population.[42] Primary individual-level risk factors for HIV acquisition identified in Uganda are high risk sexual

behaviors (e.g. early sexual debut, multiple sexual relationships, transactional sex, lack of condom use)[39,43-45] Alcohol use, presence of sexually transmitted infections, and lack of male circumcision has also been implicated.[44,45] Societal factors also increase risk for HIV. Social drivers include low education, poverty, limited access and demand for antenatal care and delivery services and low use of ART in HIV positive persons.[40]

1.4. HIV in Rakai, Uganda

Rakai District (area ~2200 km2, population ~518 000) is a mostly rural district in South-Central Uganda.[46] The district is bordered to the south by Tanzania and to the east by Lake Victoria. The capital city of Uganda is northeast of Rakai District by about 150km (Figure 1). The Rakai region has two main highways, Masaka road which connects Kampala to Tanzania and the Trans-African Highway which connects Kampala to the Democratic Republic of Congo.[41] Since the discovery of the first AIDS cases in the region,[4] HIV prevalence in the district remains among the highest in the country and is estimated to be at ~13%.[47]

A recent study on HIV transmission patterns in Rakai's agrarian and trading communities showed limited spatial clustering of HIV cases outside of households, multiple circulating HIV viruses within communities, and a significant proportion of incidence resulting from extra-community partnerships were observed.[35] Intra-household HIV accounted for approximately 39% of new incident cases in Rakai.[35] Although intra-household transmission was common, more than half of the household introductions were due to partnerships outside the community.[35] Viral introductions from extra-community partnerships presumably mediated by migration and short-term mobility, are major sources of HIV incidence in Rakai.

Preliminary data show that men from high-risk fishing communities around Lake Victoria outside the RCCS target area frequently travel to RCCS communities.[35] The high incidence of HIV

observed in young women in the study was thought to be due to the extra-community partnership they maintained with these men.[35]

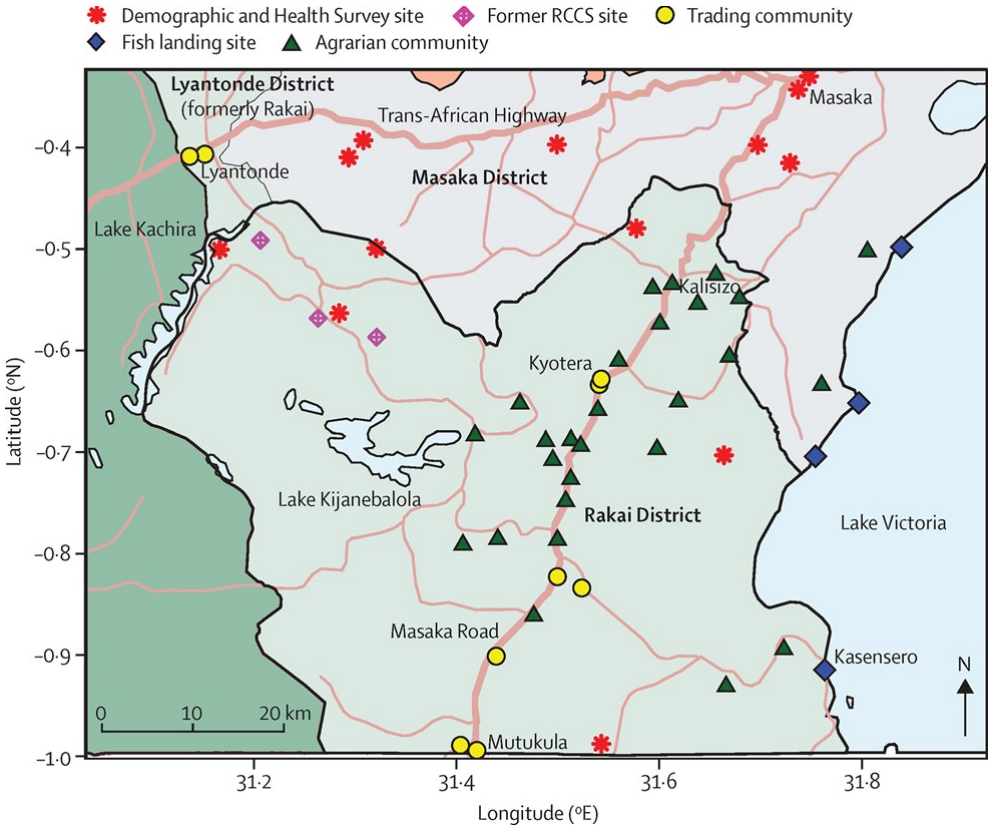

Figure 1. Map of the Rakai Region (taken from Chang et al, *Lancet HIV, 2016*)

In 2004, under the United States President's Emergency Plan for AIDS relief and the Global Fund for AIDS, Tuberculosis and Malaria, antiretroviral therapies were introduced into Uganda.[48] The Rakai Health Sciences Program (RHSP), a non-governmental entity established in the district in 1987 to study the epidemiology of HIV. RHSP initially provided ART in mobile clinics in 16 catchment areas in the district.[48,49] In 2003, Uganda switched from non-governmental provision of ART to provision of ART by the Ugandan Ministry of Health, known as "District-Led programming". Currently, RHSP provides training and oversight to government clinics under the "District-Led Programming" initiative.[50,51]

All HIV positive individuals enrolled in care are offered CD4 tests and eligible individuals are offered ART. Their CD4 counts and viral loads are also monitored every 24 to 48 weeks.[52] Furthermore, all HIV positive persons are provided a basic care package of co-trimoxazole for prophylaxis against co-trimoxazole, bed nets for malaria prevention and clean water containers with hypochlorite for prevention of diarrheal diseases.[53] The ministry of health in Uganda has adopted the 2013 WHO ART guidelines for ART initiation which starts HIV positive persons on ART if their CD4 cell count are less than or equal to 500 cells/mm^3.[52] A test and treat approach which recommends ART regardless of CD4 count has been adopted for key subgroups including: pregnant women, sero-discordant couples, fisherfolk and commercial sex workers.[52] Per WHO and PEPFAR guidelines, a combination of one non-nucleoside reverse transcriptase inhibitor (NNRTI) and two nucleoside reverse transcriptase inhibitors (NRTI) are prescribed as first line therapy. Second line regimens typically include a boosted protease inhibitor with two drugs in the NRTI class.[48,52]

Medical male circumcision is also a key component for HIV prevention in Uganda.[54] The country launched an ambitious "Safe Male Circumcision" policy in 2010 to increase prevalence of MMC to 80% by 2015.[54] In Rakai, prior to 2003, the prevalence of circumcision among non-Muslim who made up 85% of the population was approximately 4%.[54] Two trials conducted by the RHSP in 2003-2006 showed the preventive benefit of MMC in HIV acquisition[28,55] and by the end of the trial, prevalence was up to 12%.[54] With PEPFAR funding, the RHSP has provided free MMC services in the Rakai district.[54] MMCs are provided free to consenting males aged 13 or older at a central facility, four satellite centers or mobile camps throughout Rakai.

Although prevalence has remained stable, incidence has been reported to have declined from 1.17 per 100 person years in 1999 to 0.66 per 100 person years in 2016 due to scale-up of HIV prevention programs.[56] Self-reported ART use increased from 12% to 69% between 2006 and 2016 and by 2016, 61% of HIV positive men and 72% of HIV positive women reported ART use.[56]

Among all men, male circumcision coverage also significantly increased from 15% 1n 1999 to 59% in 2016, while coverage among non-Muslim men increased from 3.5% to 53% over the same period.[56]

The 90-90-90 target in viral load suppression has also been achieved in Rakai.[56] By 2016, 75% of HIV positive persons were virally suppressed compared with 42% in 2009.[56] While HIV prevention programs have been successful and 90-90-90 targets achieved, incidence however remains above elimination levels.

1.5. Barriers to HIV/AIDS Control in Uganda

Despite widespread availability of numerous HIV preventive strategies in Uganda, barriers exist to the control of HIV in the region. It is estimated that only about 40% of people eligible for ART are currently being treated in the country.[49] Studies show that linkage to care after HIV infection and retention to care are primary bottlenecks in the HIV care cascade, a series of benchmarks used to assess scale-up of ART and highlight opportunities for interventions.[57] Cost of transportation to facilities which provide treatment and preventive services has been cited in some studies as a major constraint to service utilization.[58-60] Competing needs, HIV related stigma, and personal belief about ART and HIV testing also barriers to HIV/AIDS control in Uganda.[60,61]

A fractured and underfunded health system also inhibits HIV control. Poor infrastructure, limited funds for medicines and other supplies, shortage of human resources in the public sector and negative interaction with health staff remain significant barriers to control.[59,61] Discomfort and misconceptions about preventive services also contributes to service underutilization. For example, in Rakai, men quoted pain, fear about medical complication or infertility and association with Islam as a barrier to circumcision.[62]

1.6. Migration, Mobility and HIV/AIDS in Sub-Saharan Africa

Migration is commonly defined as the movement of people in space; involving a change in usual place of residence[63] Migration may also be defined based on movement in time; which differentiates circular migration (repetitive and temporary movement often involving short periods of time away) and definite migration (permanent movement away from an original place of residence with little or no indication of return).[63] When migration occurs within national boundaries it is termed internal migration and an example of such as rural-urban migration common in many African countries.[63] When movement occurs across international borders, it is termed international migration.[63] In this thesis, we predominately assess internal migration and its impact on HIV incidence.

Many studies have linked mobility and migration to the spread of HIV/AIDS in SSA (Table 1). [64-69] Migration is considered one of the primary factors involved in driving HIV spread in cities in Africa.[70] Following independence from colonial rule in the 1960s in many African countries, mass rural-urban migration drove population growth in urban centers in SSA.[63] This migration resulted in rapid HIV spread within cities which is hypothesized to be partly a consequence of social disruption and massive urban unemployment.[63] It is also hypothesized that circular migrants moving between urban to rural settlements and back served as conduits for the spread of the infection to rural populations where prevalence was relatively low in the initial stages of the epidemic.[70]

Recent studies continue to report on associations between HIV and migration. Seroprevalence studies in Uganda, Tanzania and South Africa have all shown increased prevalence of HIV in migrants.[66,71-73] Only one study has assessed HIV incidence among African migrants. The study, conducted in South Africa, showed a significantly increased risk of HIV acquisition with circulation migration regardless of distance travelled.[74]

While prior studies have shown an association between migration and HIV, little is known about the causal pathways linking them. One hypothesis is that it is increased risky sexual behaviors in migrants leading to HIV infection. Indeed, a study in Rakai, Uganda found a higher prevalence of behavioral risk factors (e.g. multiple partnerships, inconsistent condom use) among adolescent migrants.[75] Individual predisposition and changes in baseline behavior due to the process of migration itself have been proposed as two primary reasons for the increased behavioral risk in migrants.[76] As early as 1958, Peterson theorized that migrants were inherently more adventurous or were willing to take more risks because many of them voluntarily moved to new social settings void of social support.[77] However, research from Malawi suggests that where an individual migrates to may also contribute to increased HIV risk. In Malawi, prevalence of HIV is typically higher in urban centers increasing risk through heightened exposure rather than through individual-level changes in sexual behaviors.[64,76] Moving to environments more conducive to high risk behaviors may also result in behavioral disinhibition.[64,76]

The extent to which social factors impact the association between migration and HIV has been understudied. Higher HIV prevalence among migrants may be due to limited social capital or discrimination in their new communities.[78] Lack of social support and psychological factors associated with depression and isolation may also contribute to risk.[78] Social networks of migrants are often composed of other migrants or their close and extended family.[78] Those who migrate alone typically form close family-type relationship with other migrants.[78] More limited social support and contacts within communities ultimately limits a migrant's access to resources such as paid employment, health care services and HIV education programs.[78]

Social networks formed during and after migration also impact HIV risk. Individuals who migrate on their own typically form multiple and concurrent sexual partnerships at higher rates compared to those who migrate with family.[78] Separation from a regular partner or spouse is often cited as a contributory factor in the changes in sexual behaviors that occur in migrants.[76] For example, commercial sex is common in occupations such as long distance truck driving which

involves long periods of time away from spouses.[76] There is also evidence that sexual networks among migrants tend to be cyclic, involving small groups of connected individuals who are typically migrants, rather than dendritic.[78] Cyclic network structures have been associated with increased transmission, however research on these network structures is limited.[78]

There remain critical research gaps on migration and HIV. In general, these studies have been hampered by measuring the migration itself and by characterizing migrant populations who are difficult to enroll and follow in studies. There is also little understanding about why and how people migrate which has resulted in varied and broad definitions of migration and, in some cases, conflicting findings. Many studies have generally focused on rural-urban or urban- urban migration but the migration process is likely more nuanced falling on a continuum rather than within broad groupings. Prior research has also disproportionately focused on migrating men and their partners[73,79] despite the increasing feminization of migration throughout SSA and some evidence that HIV risk associated with migration is concentrated among women.[79-81] Lastly, most studies on HIV and migration are cross-sectional. Therefore, it is largely unknown whether HIV is a cause or consequence of migration. Notably, HIV-positive individuals have been shown to be more likely to migrate in some settings.[65]

2. Methods

2.1. Study Objective

The objective of the study was to assess the association between in-migration and the incidence of HIV in thirty communities Rakai District, Uganda.

2.2. Study Hypothesis

We hypothesized that HIV incidence is higher in individuals who recently moved into Rakai communities (in-migrants) compared to long-term residents with no migration history and that this risk is mediated by higher risk sexual behaviors in migrants. We also hypothesized that HIV risk associated with in-migration would decline following scale-up of combination HIV prevention.

2.3. Conceptual Framework

Figure 2 shows a conceptual framework linking migration and HIV acquisition. This framework adapted from Soskolne, is an example of an epidemiological model where in the primary risk factor acts as disrupter of the equilibrium between the agent, the host and the environment[78]. In this case, migration causes personal and social network disequilibrium which increases risk of HIV exposure and acquisition

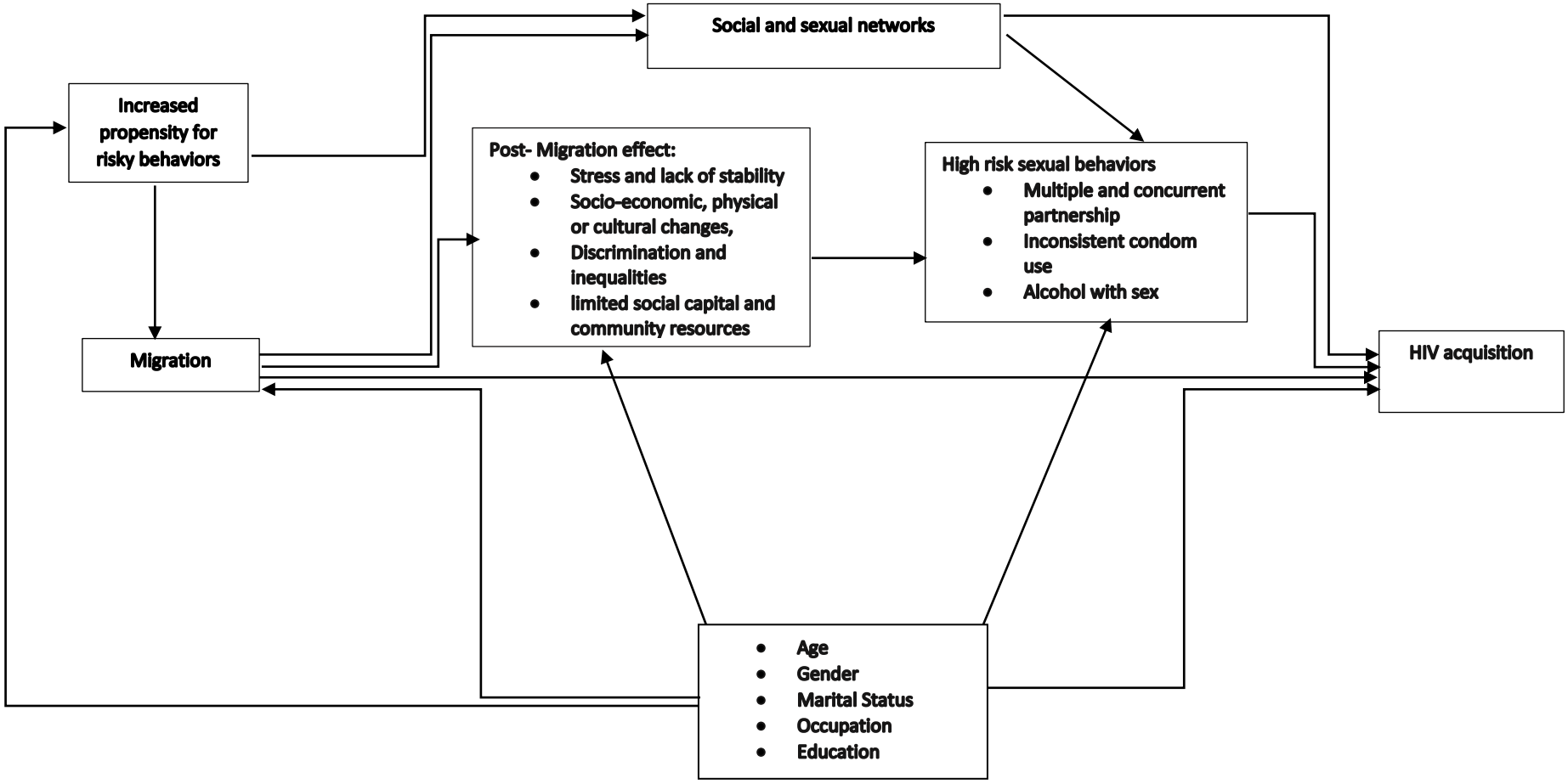

Figure 2. Conceptual Framework of HIV Acquisition in Migrants. (Adapted from Soskolne, 2007)

2.4. Study Setting, Population and Procedure

The Rakai Community Cohort Study (RCCS) is a well characterized open, population based cohort established by the Rakai Health Sciences Program (RHSP) in 1994 to study the epidemiology and prevention of HIV.[82] The RCCS originally carried out surveys in individuals aged 15-49 years in 56 communities in the district, however the number of communities surveyed has varied since the start of the study. This study uses data 30 communities continuously surveyed between April 1999 and January 2016 over 12 surveys.

The RCCS holds an informational community mobilization event. A census is then done in all the households within the community to identify eligible persons. Global positioning (GPS) coordinates for each house are recorded and all residents of the household are enumerated by age, sex and duration of residence regardless of whether they were present or absent at the time of the census. Individuals who migrate into study communities (i.e. in-migrants) and individuals who migrate out of study communities (i.e. out-migrants) are also recorded during census, and additional information on source and destination communities as well as reason for migration is obtained. After the census, eligible participants are enrolled at a central community location referred to as hubs. Other individuals who are eligible but not identified at the hubs are approached at their place of residence to request their participation. Return visits to the households are carried out up to two times if required to enroll all eligible individuals[41].

All eligible participants between the ages of 15 and 49 years who provide written consent are interviewed and information about time since arrival into a study community, demographics, sexual behaviors, antiretroviral therapy (ART) use, and male circumcision status is collected. Free HIV testing is provided after the interview. Results and counselling is offered after the test by on-site counsellors.[41] To be included in the present study, participants

were required to be HIV-seronegative at baseline and contribute a least one follow-up visit allowing for no more than one missed visit.

2.5. Laboratory Methods

Before 2011, HIV tests were performed with a laboratory-based ELISA test with confirmation by Western blot.[83] Subsequent tests have been performed with a validated parallel three test rapid HIV testing algorithm. All tests procedures followed the manufacturer's guidelines.[82] Concordant results are provided to participants with counselling and discordant results are confirmed by two enzyme immunoassays, EIA (Vironostika HIV-1, BioMerieux, and Recombigen, Cambridge Biotech). Where the EIA results are discordant, Western blots (GS HIV-1 Western Blot, Bio-Rad Laboratories, Redmond, WA, USA, BioMerieux-Vitek) or PCR are employed for confirmation.[35] Participants provide whole blood through finger prick for the rapid HIV tests performed in the field and venous blood were collected in clot activator tubes for the lab based EIAs and Western blots.[82]

2.6. Study Outcome

The outcome of the study was incident HIV infection and was defined as a first HIV seropositive test result preceded by an HIV-seronegative test at the prior visit allowing for only one missed visit. HIV infection was assumed to occur at the mid-point of the visit interval.

2.7. Primary Exposure and Confounders

In-migration into an RCCS study community was our primary exposure variable. Specifically, in-migrants were defined as participants who moved into the study area with intention to stay. For each in-migrant and at all follow-up visits, we estimated their time since arrival in a community by calculating the difference between their data of arrival in the community (ascertained by self-report) to the mid-time point their current and prior study visit. To generate our exposure variable, we first broadly classified individuals as being either long-

term residents with no migration history or in-migrants. In-migrants were then stratified by how long they had resided in the community: 0-1 years, 1-2 years, 2-3 years, 4-5 years, and greater than five years. The migration exposure was included in our models as a time-varying categorical variable where residents with no migration history served as the reference group.

Other exposure variables assessed included age, education, marital status religion, occupation and male circumcision status. Sexual behavior covariates included sex with a partner outside the community, number of sexual partners in past year, lifetime sexual partners, non-marital sexual partnerships, consistent condom use with a non-marital partner and alcohol use with sex.

We also analyzed HIV incidence in three calendar time periods: 1999-2004, 2004-2011, 2011-2015. In the earliest these time periods, there was no antiretroviral therapy or voluntary medical male circumcision programs in Rakai. Antiretroviral therapy was introduced in Rakai in 2004 and subsequently scaled according to WHO guidelines. Male circumcision programs for HIV prevention were introduced in 2007. Our second calendar time included 2004-2011 early during scale-up of these two biomedical interventions. The latest time period covers the most recent phase of combination HIV prevention scale-up in Rakai. Median ART and male circumcision coverage in the early combination HIV prevention period (2004-2011) was 20% and 31% respectively. In late CHP period, median ART coverage was 62% and median MC coverage was 56%.

2.8. Statistical Analysis

Baseline and sexual behavior characteristics of in-migrants and residents were compared using proportions for categorical and binary variables and median and interquartile ranges (IQR) for continuous variables. Statistically significant differences were assessed using chi-square tests for categorical and binary variables and Wilcoxon rank sum tests for continuous variables.

The unit of analysis was person-intervals of follow-up. Poisson regression models with generalized estimating equations (GEE) with an exchangeable correlation structure were used to estimate incidence rate ratio (IRR) of HIV and 95% confidence interval (95% CI) associated with migration. Multivariate analyses were first conducted only adjusting for demographics and calendar time. In a separate multivariate analysis, we hypothesized were mediators of the association migration and HIV risk. Analyses were also stratified by gender and by calendar time. In a sub-analysis including only migrants, place of origin and distance travelled and reason for movement were assessed as risk factors for HIV acquisition.

Lastly, a sensitivity analysis was performed to account for loss to follow up and selection bias using inverse probability survey weights. Inverse probability weighting was implemented using methods previously described by Cole et al[84]. Briefly, models for survey participation and censoring were specified separately. Each person-visit was treated as an observation in the models which included the time-fixed and time-varying variables specified in the table above. Our model of survey participation included variables collected at time of census (age, gender and community of residence) whereas the censoring model included demographic and sexual behavioral variables collected at census and time of survey. The denominator of the weights was a logistic regression model for the probability of contributing person-time to the incidence cohort which was defined as the joint probability of participating in the survey and of being observed at the following survey. The numerator was the joint probability of the marginal distributions for participation and censoring. Weighted incidence rate ratios were estimated using Poisson regression assuming independence between individual participant observations conditional on observed covariates.

2.9. Ethical Consideration

All study participants provided written informed consent at baseline and follow-up visits using institutional review board approved forms. This study was reviewed and approved by the Ugandan

Virus Research Institute Security and Ethics Committee and the Western institutional review board (Protocol #20031318). This analysis was exempt from the Johns Hopkins Bloomberg School of Public Health (JHSPSH) institutional review board because it was a de-identified secondary data analysis.

3. RESULTS

3.1. Baseline demographics of the study population

There were 26,995 individuals were eligible for participation of which 16,165 individuals contributed two or more visits and were included in the analysis. 55% (n=8789) were women and 28% (n=4529) were classified as in-migrants. Participants contributed 69,231 person-visits at which 851 incident HIV events were identified (n=357 in men; n=492 in women).

Demographic characteristics of participants at baseline are shown in Table 2. The median age was 22 years for both in-migrant and resident women while in-migrant men were slightly older than resident men (26 vs. 21 years in residents). Among women, 57.1% (1768/3099) of in-migrants were in a monogamous marriage compared to 38.3% (2178/5690) of residents. In-migrant men (44%, 634/1430) were also more likely to be married compared to resident men (33%, 1974/5946). Majority of the participants regardless of migration status had a primary education; however, a higher proportion of in-migrants had technical or university education: 10% (313/3099) in migrant women and 16% (233/1430) in migrant men compared to 5% (269/5690) and 6% (338/5946) in resident women and men respectively. Agricultural work was the most common primary occupation among migrant women and men (41% among in-migrants vs. 46% among residents). Migrant and resident men reported administrative work as their most common primary occupation (28% among in-migrants vs. 39% among residents). Among men, male circumcision was slightly higher among in-migrants (25%, 356/1430) than in residents (18%, 1096/5946). All demographic differences were statistically significant.

3.2. Sexual behaviors by migration status

Selected sexual behaviors of the in-migrants and residents are shown in Table 3. Overall, in-migrants of both genders had somewhat higher levels HIV-related risk behaviors. While there was no statistically significant difference in non-marital partnership between migrant and resident women, in-migrant men were significantly more likely to report non-marital partnerships (57%, 815/1430 vs. 47%, 791/ 5946; p= < 0.0001). Among those who reported non-marital partnerships, in-migrants of both genders were less likely to consistently use condoms (24% vs. 28% in women, p=0.029; 39% vs. 42% in men, p=0.015). Sex with partners outside the community was more common among migrants of both genders. Among women, 23% of in-migrants (715/3099) reported having sexual relationships with partners outside the community compared to 15% of residents (859/5690) (p= <0.0001). Among men, 39% (558/1430) of in-migrants reported sex with partners outside the community compared to 25% (1480/5946) of resident men (p= <0.0001).

In-migrant men also tended to report more sexual partners in the past year compared to residents. For example, 34% of migrant men (485/1430) reported having 2-3 sexual partners compared to 24% (1444/5946) of resident men (p= <0.0001). Migrants of both genders also reported more lifetime sexual partners. Among men, 25% (359/1430) of in-migrants reported greater than five lifetime partners compared to 18% (1074/5946) residents (p= < 0.0001). Similarly, 55% (1711/3099) of in-migrant women reported 2-3 partners compared to only 40% (2254/5690) of resident women (p= < 0.0001).

3.3. HIV Incidence among in-migrants and residents

A total of 849 HIV incident events occurred over 93,437 person years of follow-up, of which 29% (n=243) occurred among in-migrants. HIV incidence rates and incidence rate ratios comparing migrants by time since arrival in the community to residents with no migration history is shown in Table 4. HIV incidence was higher among in-migrants compared to residents

regardless of gender. HIV incidence among women who migrated in the prior year was 2.19/100 person-years (py) compared to 0.91/100 py in resident women (IRR = 2.00, 95% CI: 1.02-3.89). Risk remained elevated after adjustment with demographics adjIRR$_{dem}$ = 1.73, 95% CI: 0.90-3.37) but not with adjustment for demographics and sexual behaviors (adjIRR$_{dem+ sex}$= 0.58, 95% CI: 0.16-2.19). Female HIV incidence between 1-2 years after migration was also significantly higher at 1.85/100 py (IRR = 2.12, 95% CI: 1.61-2.80). This risk persisted after both adjustment for demographics and sexual behaviors (adjIRR$_{dem}$= 1.83, 95% CI: 1.36-2.46; adjIRR$_{dem+ sex}$= 2.53, 95% CI: 1.68-3.79). After two years of living in the community, HIV risk among migrant women was similar to long-term female residents. We also found statistically significant elevated HIV risk in the first two years following migration among men. Specifically, HIV incidence was 1.86 per 100 py among men who had migrated into the community in the last year (IRR = 2.01, 95% CI: 0.49-8.21), 1.41 per 100 py among men who had migrated 1-2 years prior (IRR = 1.81, 95% CI: 1.13-2.89), and 0.79 per 100 py among resident men. Risk also declined among men after these first two years.

Because elevated HIV risk was largely concentrated in the first two years following the migration event, we next simplified our migration exposure into three categories: residents with no migration history, recent in-migrants (arrived <2 years), and non-recent migrants (> 2 years since arrival). In this more parsimonious analysis, HIV risk was significantly increased in the first two years after adjustment for demographics and sexual behaviors in both genders and in the full population (Table 5). Overall, HIV incidence was two-fold higher in recent migrants compared to residents (adjIRR$_{dem+ sex}$= 2.02, 95% CI: 1.47-3.79). Sensitivity analyses with inverse probability weights did not change these inferences (Table 6).

To assess the effect of combination HIV prevention (CHP) scale-up on HIV incidence in migrants and non-migrants, we further stratified our analysis by calendar period (Table 7). We find that while HIV incidence substantially declined in resident and non-recent migrants over time, HIV

incidence remained persistently high among recent migrant men and women. In the latest calendar period (2011-2015) with high levels of CHP coverage, HIV incidence was 1.76/100 py in recent migrant women and 1.45/100 py in recent migrant men compared to 0.61/100 pys and 0.48/100 pys in resident women and men, respectively. While HIV incidence declined by 42% and 56% in resident women and men, there were no significant HIV incidence declines among recent migrants.

3.4. Risk of HIV among in-migrants

The characteristics of in-migrants based on their reasons for moving to Rakai and their place of origin are shown of Table 8. Among women, movement to live with a friend/ relative and movement due to a new marriage or consensual relationship were the most common reasons for migration (37.0% and 36.2% respectively). In contrast, men most commonly reported migrating for work (44.4%) or to start a new household (28.7%). Most migration was local with largest numbers of migrants moving between communities within the district accounting (46% and 51% of migration events in men and women, respectively). Common places of origin outside Rakai included the neighboring Masaka District and the capital city, Kampala. Overall, more than half of migrants were moving from communities <30 kilometers away.

HIV incidence rates by reason for migration, place of origin, and distance traveled are shown in Table 9 stratified by gender. HIV incidence was highest among women moving to start a new household and men who were newly married. There were no trends in risk for HIV by distance traveled or place of origin.

4. DISCUSSION

In this longitudinal population-based study, we find that in-migrants have higher HIV incidence and higher prevalence of high risk sexual behaviors compared to community residents with no migration history. We also show that elevated HIV risk associated with migration is highest in first two years following migration event and declines thereafter. Critically, we find that despite significant HIV incidence declines in residents with scale-up of combination HIV prevention, HIV incidence has remained persistently high in recent migrants. To our knowledge this is the first study to use longitudinal-based population based data to assess the time at which migrants are at highest risk for HIV acquisition following migration.

In our study population, more women were classified as migrants than men, a finding which likely reflects the increasing feminization of migration observed throughout SSA.[79,80] It is hypothesized that the higher proportions of migrating African women may be due to women seeking economic independence or increased familial responsibilities independent of male partners.[75] However, we found that migrants were more likely to be married compared to residents and women were most likely to move because of marriage. Our results also show migrant men were slightly older than residents which is inconsistent with prior studies reporting that mobile men are typically younger and unmarried. Notably, women have restricted access to land and assets in Uganda resulting in financial dependence that makes them more likely to move to the residence of their male partners.[85]

We observed significantly higher levels of high risk sexual behaviors among migrants compared to residents which is consistent with previous studies showing migrants tend to have higher HIV risk profiles.[66-68,81] Both male and female in-migrants reported more sexual activity, greater proportions of lifetime sexual partners, non-marital partnerships and sex with partners outside the community. They were also less likely to report consistent condom use with a non-

marital partner. An earlier study from Rakai found that sex with extra-community partners was associated with substantially increased risk among women.[35]

Taken together, our results support the hypothesis that in-migrants have a higher risk of HIV acquisition. Notably, HIV risk was highest in the first two years following the migration event suggesting that interventions targeted to migrants would need to intervene early in the settlement process. This higher HIV risk among recent migrants may be due in part to higher levels of sexual risk behaviors during the migration process, but migration remained associated with HIV acquisition even after adjustment for sexual behaviors suggesting causal pathways independent of individual level behaviors. Similar findings were observed in a cross-sectional study in Tanzania where the odds of HIV infection were ~ 2.4 in recent male and female in-migrants compared to residents.[72] The study also found an inverse association between risk behaviors and time after in-migration which we did not examine here.

Of key importance to HIV control, we found that HIV incidence has remained high in migrants despite substantial scale-up of combination HIV prevention. While HIV incidence has declined substantially among residents, incidence has remained high among recent in-migrants with minimal evidence of decline. Our results suggest that ongoing HIV prevention programs have had minimal impacts on migrant populations.

Prior research suggests that female migrants are most at risk for HIV.[76,80,81] This trend was also observed in this study with female in-migrants having consistently statistically significant increased HIV incidence compared to men across CHP scale-up period. The increased risk behaviors also observed among female in-migrants suggests that women are in part putting themselves at risk through their own behaviors.[81] The structural and economic barriers women face may compel them to engage in these risky behaviors for survival such as commercial sex work.[76,86]

The earliest years following migration are associated increased vulnerability, particularly amongst young people. The immediate period after migration is associated with increased instability, detachment from family, friends, and previous community and changing social norms. This social disruption likely promotes HIV risk behaviors such as multiple partnerships, casual relationships and inconsistent condom use as observed in this study and, consequently, increased risk of HIV acquisition. Unfortunately, prior research suggests that linking migrants to HIV treatment and prevention programs is challenging.[87] Migrants often learn about their HIV status long after infection,[87,88]reducing the likelihood of early treatment initiation and suppression. Reluctance of HIV-positive migrants to link to and remain in care has been linked to stigma, frequent and circular migration, unfamiliarity with new environment and lack of knowledge about the new health systems.[87]

There is a need to identify recent migrants and link them into health services. Programmatic tools to effectively identify new migrants in communities are currently lacking. The use of mobile technology has previously been suggested.[89,90] Community health workers who travel outside clinics to locate patients in the community have been employed in some settings to aid retention in care[91] and may also be useful to in engaging migrant populations. However, special ethical considerations may need to be made for programs targeted to migrants. Migration is a diverse process that is sometimes circular, international or internal and may be intentional or forced. In particular, forced migrants may have special need that would need to be addressed in programmatic design. Cultural and language barriers facing migrants in their new communities should also be accounted for when implementing services.[87]

4.1. Strengths and Limitations

There are important limitations to this study. Demographic and sexual behavior data were self-reported and could have been subject to social desirability bias. Participation and follow-up rates may have resulted in selection bias however; the analyzed sample size was still large and results from sensitivity analysis using inverse probability weights did not change the inference drawn from the study. We did not assess the association between circular migration and HIV incidence or urban-rural migration patterns. Based on the conceptual framework used in this study, the sexual behaviors in this study could have been mediators of the association of migration and HIV and adjusting for them could have attenuated some of the effect size, however, the magnitude of the effect remained similar after adjustment. There is also the potential for residual or unmeasured confounding. Finally, the external validity of this study should be considered before generalizing the findings to other populations outside Rakai. Unique characteristics of Rakai may limit extrapolating this finding to other studies. However, RCCS demographic and behavioral data are consistent with other surveys carried out in the region.[92]

Apart from the novelty of our study in measuring incidence following migration in a mobile population, the use of a well characterized population-based longitudinal data allowed us to effectively characterize the migration exposure.

4.2. Conclusion

In conclusion, we find that the first two years following migration is associated with substantially increased HIV risk. HIV incidence remains high among in-migrants compared to residents even with scale-up of HIV prevention programs in Rakai. Active surveillance, identification and retention of migrant population in HIV prevention and treatment programs is needed to reduce the burden of HIV in Rakai.

Tables

Table 1: Summary of selected publications linking migration and/or mobility and HIV in Sub-Saharan Africa

Authors [REF]	Location	Study Type	Incidence/Prevalence Measured	Main Findings
Dobra et al [74]	South Africa	Population-based cohort study	Incidence	Increased risk of HIV acquisition with larger average distance travelled and increased time outside the study area.
Anglewicz et al[65]	Malawi	Population-based cohort study	Prevalence (Odds of migration given HIV status)	HIV positive individuals were more likely to migrate out of rural areas to urban areas, however HIV positive Individuals were also more likely to return to their village of origin
Schuyler et al[66,75]	Uganda	Population-based cohort study	Prevalence	Mobile youths were more likely to report behavioral risk factors for HIV.
Kishamawe et al[66]	Tanzania	Longitudinal cohort study	Prevalence	Increased sexual risk behavior and HIV prevalence in mobile individuals and the partners who remained behind
Lagarde et al[67]	Guinea Bissau/ Senegal	Cross-sectional survey	Prevalence	Short term mobility associated with increased risk behaviors and increased HIV prevalence.

Nunn et al[71]	Uganda	Longitudinal cohort study	Prevalence	Change of residence associated with increased risk of HIV-1 infection likely due to increased risky sexual behavior among those who move
Mmbaga et al[72]	Tanzania	Cross-sectional survey	Prevalence	HIV prevalence was higher in migrants, but higher in recent in-migrants. The odds of HIV infection were also higher in recent in-migrants. Risk behaviors was inversely related to years since in in-migration.
Lurie et al[73]	South Africa	Cross-sectional survey	Prevalence	Migration was a significant independent risk factor for HIV infection.
Lydie et al[68]	Cameroon	Cross-sectional survey	Prevalence	Mobile men reported riskier sexual behaviors and HIV infection increased with time away from home
Coffee et al[69]	South Africa	Modelling based on population-based cohort study data	Prediction model of HIV prevalence	Migration coupled with increased sexual risk behavior among migrant men would increase the prevalence of HIV among the migrants' female partners

Camlin et al[81]	South Africa	Cross sectional study	Prevalence (Odds of HIV infection)	Female migrants had higher odds of HIV infection compared to male and female non-migrants. Each additional lifetime sexual partner was associated with a 22% increase in the odds of HIV infections for female migrants. The association was not significant in migrant men.

Table 2: Demographic characteristics at baseline or first visit following in-migration

	Women (n= 8789)			Men (n=7376)		
	In-migrants 3099 (35.3)	**Residents 5690 (64.7)**	**p. value**	**In-migrants 1430 (19.4)**	**Residents 5946 (80.6)**	**p.value**
Median Age (IQR)	22(19-27)	22(17-30)	<0.0001	26(17-30)	21(16-29)	<0.0001
Age category						
15-19	908(29.3)	2141(37.6)		258(18.0)	2650(44.6)	
20-24	1065 (34.4)	1186(20.8)		381 (26.6)	1062(17.9)	
25-29	605 (19.5)	884(15.5)	<0.0001	355 (24.8)	844(14.2)	<0.0001
30-34	257(8.3)	496(8.7)		192 (13.4)	588(9.9)	
35-39	139 (4.5)	406(7.1)		122(8.5)	368(6.2)	
40 or Older	125 (4.0)	577(10.1)		122(8.5)	434(7.3)	
Marital Status						
Monogamous	1768 (57.1)	2178 (38.3)		634(44.3)	1974(33.2)	
Never Married	555(17.9)	2211(38.9)		596(41.7)	3421(57.5)	
Polygamous	373 (12.0)	606(10.6)	<0.0001	106(7.4)	325(5.5)	<0.0001
Previously Married	401 (12.9)	692(12.2)		92(6.4)	212(3.6)	
Data Missing	2 (<1)	3 (<1)		2(<1)	14(<1)	
Educational Status						
Primary	1720 (55.5)	3367 (59.2)		755(52.8)	3719(62.6)	
Secondary	911 (29.4)	1733(30.5)	<0.0001	357(25.0)	1633(27.5)	<0.0001
Technical/University	313(10.1)	269(4.7)		233(16.3)	338(5.7)	
None	138 (4.5)	289(5.1)		61(4.3)	165(2.8)	
Data Missing	17 (<1)	32 (<1)		24(1.7)	91 (1.5)	

Religion						
Catholic	1930 (62.3)	3778 (66.4)		823(57.6)	3942(66.3)	
Muslim	409 (13.2)	751(13.2)		174(12.2)	762(12.8)	
Protestant	572(18.5)	937 (16.5)	<0.0001	315(22.0)	970(16.3)	<0.0001
Saved/Pentecostal	148 (4.8)	143(2.5)		76(5.3)	145(2.4)	
None/Other	23 (0.7)	49 (0.9)		18(1.3)	36(0.6)	
Data Missing	17(<1)	32(<1)		24(1.7)	91(1.5)	
Occupation						
Agriculture	1274(41.1)	2605 (45.8)		335(23.4)	1517(25.5)	
Administrative/Teaching	519 (16.8)	1676(29.5)		396(27.7)	2313(38.9)	
Bar	62 (2.0)	80 (1.4)	<0.0001	6(0.4)	16(0.3)	<0.0001
Trading	379 (12.2)	455 (8.0)		212(14.8)	747(12.6)	
Other	865 (27.9)	874(15.4)		481(33.6)	1353(22.8)	
Male Circumcision						
No	-	-		1072(75.0)	4834(81.3)	
Yes				356(24.9)	1096(18.4)	<0.0001
Data Missing				2(<1)	16(<1)	

Data are number (%) unless otherwise specified. Some percentages do not add to 100 because of rounding

Table 3: Sexual risk behaviors at baseline or first visit following in-migration

	Women (n= 8789)			Men (n=7376)		
	In-migrants 3099 (35.3)	**Residents 5690 (64.7)**	**p.value**	**In-migrants 1430(19.4)**	**Residents 5946 (80.6)**	**p.value**
Non-marital partnership						
No	2165(69.9)	4012(70.5)	0.525	615(43.0)	3155(53.1)	<0.0001
Yes	934(30.1)	1678(29.5)		815(57.0)	2791(46.9)	
Sex in the past year with a partner residing outside the community						
Not sexually active/ No sex in past year	285(9.2)	1664(29.2)	<0.0001	251(17.6)	2095(35.2)	<0.0001
No	2097(67.7)	3167(55.7)		621(43.4)	2369(39.8)	
Yes	715(23.1)	856(15.0)		558(39.0)	1480(24.9)	
Data Missing	2 (<1)	3(<1)		-	2(<1)	
Consistent condom with non-marital partners						
No	707(75.7)	1204(71.8)	0.029	1548(60.6)	7179(58.0)	0.015
Yes	227(24.3)	474(28.3)		1005(39.4)	5190(42.0)	
Number of lifetime sexual partner						
1	656(21.2)	1425(25.0)	<0.0001	128(9.0)	581(9.8)	<0.0001
2-3	1711(55.2)	2254(39.6)		324(22.7)	1174(19.7)	
3-5	451(14.6)	617(10.8)		276(19.3)	864(14.5)	
Greater than 5	138(4.5)	202(3.6)		359(25.1)	1074(18.1)	
Can't Remember/Unknown	22(0.7)	61(1.1)		215(15.0)	650(10.9)	
No partner ever/ Not sexually active	114(3.7)	1105(19.4)		126(8.8)	1579(26.6)	
Data Missing	7(<1)	26(<1)		2(<1)	24(<1)	

Number of different sexual partners in the past year						
1	2486(80.2)	3813(67.0)		622(43.5)	2165(36.4)	
2-3	313(10.1)	210(3.7)		485(33.9)	1444(24.3)	
3-5	4(0.1)	3(0.05)	<0.0001	46(3.2)	148(2.5)	<0.0001
Greater than 5/Can't remember	2(0.06)	2(0.04)		28(2.0)	102(1.7)	
No sex in the past year/ Not sexually active	292(9.4)	1659(29.2)		249(17.4)	2085(35.1)	
Data Missing	2(0.06)	3(0.05)		-	2(<1)	
Alcohol with sex[#]						
No	2326(77.9)	3452(75.3)	0.026	922(70.7)	2930(67.1)	
Yes	654(21.9)	1127(24.6)		376(28.8)	1425(32.6)	0.023
Data Missing	5(<1)	6(<1)		6(<1)	12(<1)	

 # In participants who reported being sexually active

Data are number (%) unless otherwise specified. Some percentages do not add to 100 because of rounding

Table 4: Model A, gender stratified crude and adjusted HIV incidence rate and incidence rate ratio by time since in-migration

Women					
Migrant category	**No of Events/ py* at risk**	**Incidence rate per 100 py (95%CI)**	**Crude IRR (95% CI)**	**Adjusted IRR++ (95% CI)**	**Adjusted** IRR (95% CI)**
Residents	320/35269.15	0.91(0.81-1.01)	REF	REF	REF
In-migrants, 0-1 year	9/410.63	2.19(1.14-4.21)	2.00(1.02-3.89)	1.73(0.90-3.37)	0.58(0.16-2.19)
In-migrants, 1-2 years	61/3301.00	1.85(1.44-2.38)	2.12(1.61-2.80)	1.83(1.36-2.46)	2.53(1.68-3.79)
In-migrants, 2-3 years	21/1984.58	1.06(0.69-1.62)	0.98(0.62-1.54)	0.90(0.56-1.43)	1.17(0.59-2.29)
In-migrants, 3-4 years	20/2112.48	0.94(0.61-1.47)	1.28(0.81-2.01)	1.13(0.71-1.79)	1.42(0.73-2.74)
In-migrants, 4-5 years	10/1345.78	0.74(0.40-1.38)	0.86(0.45-1.62)	0.80(0.42-1.53)	0.99(0.35-2.82)
In-migrants, > 5 years	51/6342.38	0.80(0.61-1.06)	0.91(0.67 -1.22)	0.95 (0.69-1.31)	0.82(0.47-1.43)
		Men			
Migrant category					
Residents	286/36157.90	0.79(0.70-0.89)	REF	REF	REF
In-migrants, 0-1 year	2/107.63	1.86(0.46-7.42)	2.01(0.49-8.21)	2.03(0.49-8.45)	3.22(0.73-14.1)
In-migrants, 1-2 years	19/1349.83	1.41(0.90-2.21)	1.81(1.13-2.89)	1.77(1.11-2.84)	1.81(0.99-3.29)
In-migrants, 2-3 years	10/917.05	1.09(0.59-2.03)	1.31(0.69-2.48)	1.17(0.61-2.25)	1.66(0.82-3.35)
In-migrants, 3-4 years	7/874.90	0.80(0.38-1.68)	1.30(0.61-2.76)	1.19(0.55-2.56)	0.97(0.34-2.74)
In-migrants, 4-5 years	6/666.51	0.90(0.40-2.00)	1.34(0.59-3.03)	1.30(0.57-2.97)	1.37(0.49-3.81)
In-migrants, > 5 years	27/2596.79	1.03(0.71-1.52)	1.35(0.90-2.02)	1.44(0.95-2.21)	1.28(0.70-2.35)

		All Participants			
Migrant category					
Residents	606/71427.05	0.85(0.78-0.92)	REF	REF	REF
In-migrants, 0-1 year	11/518.27	2.12(1.18-3.83)	2.09(1.14-3.81)	1.81(0.99-3.30)	0.97(0.36-2.55)
In-migrants, 1-2 years	80/4650.84	1.72(1.38-2.14)	2.10(1.66-2.65)	1.83(1.43-2.35)	2.22(1.61-3.06)
In-migrants, 2-3 years	31/2901.63	1.07(0.75-1.52)	1.10(0.76-1.59)	0.99(0.67-1.45)	1.30(0.80-2.12)
In-migrants, 3-4 years	27/2987.38	0.90(0.62-1.32)	1.32(0.90-1.95)	1.14(0.77-1.69)	1.20(0.70-2.09)
In-migrants, 4-5 years	16/2012.30	0.80(0.49-1.30)	1.02(0.62-1.69)	0.91(0.55-1.52)	1.07(0.51-2.22)
In-migrants, > 5 years	78/8939.17	0.87(0.70-1.09)	1.05(0.83-1.34)	1.04(0.81-1.35)	0.91(0.60-1.36)

[*] **person-years**

[++] **Adjusted for demographics alone**

****Adjusted for demographics and sexual behavior**

Table 5: Model B, gender stratified crude and adjusted HIV incidence and incidence rate ratio by time since in-migration

Women					
Migrant category	**No of Events/ py* at risk**	**Incidence rate per 100 py (95%CI)**	**Crude IRR (95% CI)**	**Adjusted IRR++ (95% CI)**	**Adjusted IRR** (95% CI)**
Residents	320/35269.15	0.91(0.81-1.01)	REF	REF	REF
In-migrant, 0-2 years	70/3711.64	1.89(1.49-2.38)	2.10(1.62-2.73)	1.81(1.37-2.41)	2.15(1.44-3.22)
In-migrants, > 2 years	102/11785.22	0.87(0.71-1.05)	0.97(0.77-1.22)	0.95(0.74-1.22)	1.03(0.69-1.52)
Migrant category		**Men**			
Residents	286/36157.90	0.79(0.70-0.89)	REF	REF	REF
In-migrant, 0-2 years	21/1457.47	1.44(0.94-2.21)	1.83(1.17-2.86)	1.79(1.14-2.82)	1.92(1.09-3.39) ^
In-migrants, > 2 years	50/5055.25	0.99(0.75-1.30)	1.33(0.98-1.81)	1.32(0.97-1.82)	1.34(0.88-2.02) ^
Migrant category		**All Participants**			
Resident	606/71427.05	0.85(0.78-0.92)	REF	REF	REF
0-2 years	91/5169.11	1.76(1.44-2.16)	2.10(1.68-2.62)	1.83(1.45-2.32)	2.02 (1.47-2.77)
In-migrants, > 2 Years	152/16840.47	0.90(0.77-1.06)	1.10(0.92-1.32)	1.03(0.85-1.26)	1.07(0.81-1.43)

*person-years

++ Adjusted for demographics alone

**Adjusted for demographics and sexual behaviors

^ Some categories of religion and occupation excluded due to small numbers

Table 9: Sensitivity analysis, gender stratified crude and adjusted incidence rate ratio of HIV by time since in-migration using inverse probability survey weights

Migrant category, Women	Crude IRR (95% CI)	Adjusted IRR[++] (95% CI)	Adjusted IRR** (95% CI)
Residents	REF	REF	REF
In-migrants, 0-2 years	2.79(1.91-4.07)	2.24(1.50-3.35)	2.11(1.40-3.18)
In-migrants, > 2 years	1.25(0.88-1.78)	1.07(0.73-1.57)	1.00(0.67-1.48)
Migrant category, Men			
Residents	REF	REF	REF
In-migrants, 0-2 years	1.83(1.06-3.14)	1.81(1.03-3.17)	1.70(0.96-3.05)
In-migrants, > 2 years	1.51(1.01-2.26)	1.31(0.86-2.00)	1.34(0.87-2.06)
Migrant category, All participants			
Residents	REF	REF	REF
In-migrants, 0-2 years	2.58(1.90-3.49)	1.99(1.44-2.74)	1.90(1.38-2.63)
In-migrants, > 2 years	1.45(1.12-1.90)	1.09(0.82-1.46)	1.06(0.79-1.42)

[++] **Adjusted for demographics alone**

****Adjusted for demographics and sexual behavior**

Table 7: Adjusted IRR of HIV by time since in-migration, stratified by gender and combination HIV (CHP) scale-up period

	Women		Men	
CHP scale-up period	**Incidence/100 *py (95% CI)**	**Demographics adjIRR (95%CI)**	**Incidence/100 py (95% CI)**	**Demographics adjIRR (95% CI)**
Pre-CHP (1999-2004)				
Residents	1.05	REF	1.09 (0.89-1.33)	REF
In-migrants, 0-2 years	1.86	2.03 (1.25-3.29)	1.22 (0.55-2.71)	1.43 (0.63-3.29)
In-migrants, > 2 years	1.08	1.19 (0.69-2.05)	1.43 (0.74-2.74)	1.61 (0.81 – 2.30)
Early-CHP (2005-2011)				
Residents	0.99 (0.84-1.15)	REF	0.83 (0.71-0.98)	REF
In-migrants, 0-2 years	1.97 (1.40-2.77)	1.61 (1.06-2.45)	1.64 (0.85-3.14)	1.74 (0.85 – 3.53)
In-migrants > 2 years	0.96 (0.74-1.25)	0.84 (0.60-1.18)	1.22 (0.85-1.74)	1.30 (0.51-1.97)
Late-CHP (2011-2015*)*				
Residents	0.61 (0.47-0.79)	REF	0.48 (0.36-0.63)	REF
In-migrants, 0-2 years	1.76 (1.06-2.92)	1.97 (1.07 – 3.66)	1.45 (0.65-3.22)	2.42 (1.00 – 5.87)
In-migrants, > 2 years	0.69 (0.49-0.97)	1.06 (0.65-1.73)	0.56 (0.31-1.01)	1.21 (0.61 – 2.36)

*person-years

Table 8: Gender stratified in-migration characteristics

In-migration Characteristics	Women	Men
Reasons for In-migration		
Newly Married/New consensual	1122(36.2)	24(1.7)
Work	620(20.0)	635(44.4)
Started New Household	180(5.8)	410(28.7)
Living with relatives/friends	1145(37.0)	276(19.3)
Other reasons[1]	32 (1.0)	85 (5.9)
In-migration Origin		
Rakai District	1588 (51.2)	651 (45.5)
• Kasasa	164 (10.3)	70 (10.8)
• Kyotera	336 (21.2)	131 (20.1)
• Lwanda	219 (13.8)	95 (14.6)
• Kakuuto	214 (13.5)	95 (14.6)
• Kabira	138 (8.70)	58 (8.9)
• Kalisizo	186 (11.7)	58 (8.9)
• Kitumba	116 (7.3)	61 (9.4)
• Kyanamukaaka	85 (5.4)	32 (4.9)
• Kyebe	77 (4.9)	31 (4.8)
• Lyantonde	53 (3.3)	20 (3.1)
Masaka District	178 (5.7)	82 (5.9)
Elsewhere in Rakai	520 (16.7)	189 (13.2)
Kampala	187 (6.0)	136 (9.5)
Elsewhere in Uganda	295 (9.5)	136 (9.5)
Outside Uganda	42(1.4)	17 (1.2)
Unknown	226 (7.3)	182 (12.7)
Missing	63 (2.0)	34 (2.4)
Distance from In-migration Origin		
0-5 Kilometers	651 (21.0)	317(22.2)
5-15 Kilometers	844 (27.2)	283(19.8)

15-30 Kilometers	606 (19.6)	227 (15.9)
30-90 Kilometers	466 (15.0)	234(16.4)
90-180 Kilometers	267 (8.6)	129 (9.0)
Greater than 180 Kilometers	265 (8.6)	240 (16.8)

Data are number (%) unless otherwise specified. Some percentages do not add to 100 because of rounding
[1]Other reasons include: Divorced/Separated, Education, Polygamous man travelling between household

Table 9: Gender stratified incidence rate of HIV by in-migration

In-migration Characteristics	Incidence Rate/100 py* (95% CI)	Incidence Rate/100 py (95% CI)
Reasons for In-migration	**Women**	**Men**
Newly Married/New consensual relationship	1.06 (0.82-1.35)	2.20 (0.71-6.82)
Work	1.14 (0.82-1.58)	0.97 (0.67-1.41)
Started new household	2.00 (1.29 -3.10)	0.92 (0.60-1.42)
Living with Relative/friend	0.94 (0.72 – 1.23)	1.28 (0.79 – 2.10)
Other Reasons[1]	-	0.72 (0.23 – 2.22)
In-migration Origin		
Rakai District	1.04 (0.88-1.24)	1.06 (0.78-1.46)
Masaka District	1.43 (0.90-1.75)	1.15 (0.48-2.76)
Elsewhere in Rakai	1.29 (0.95-1.75)	1.05 (0.52-2.10)
Kampala	1.32 (0.81-2.17)	1.02 (0.42-2.44)
Elsewhere in Uganda	0.77(0.47-1.26)	1.24 (0.59-2.61)
Outside Uganda	0.35 (0.049-2.48)	-
Unknown	0.71 (0.43-1.17)	0.58 (0.24-1.39)
Distance from In-migration Origin		
0-5 kilometers	1.06 (0.77-1.46)	1.46 (1.00-2.16)
5-15 kilometers	0.99 (0.74-1.32)	0.92 (0.55-1.56)
15-30 kilometers	1.05 (0.75-1.47)	0.77 (0.39-1.54)
30-90 kilometers	1.33 (0.92-1.92)	1.01 (0.54-1.88)
90-180 kilometers	1.46 (0.91-2.35)	1.03 (0.46-2.30)
Greater than 180 kilometers	0.81 (0.45-1.46)	0.66 (0.31-1.38)

*** person-years**

[1]Other reasons include: Divorced/Separated, Education, Polygamous man travelling between household

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Infectious Disease Dynamics Group, Johns Hopkins Bloomberg School of Public Health

- Mapping Cholera burden and risk factor in West Africa using spatial demographic data to improve cholera incidence estimates in the region for appropriate planning and distribution of limited vaccine supplies

Graduate Research Assistant
Jul 2016 - present
Rakai Health Sciences Program, Johns Hopkins Bloomberg School of Public Health

- Critical appraisal and literature review on social and sexual networks of migrant populations
- Epidemiological modelling and statistical analysis of longitudinal HIV survey data
- Preparation of posters and manuscripts for submission to academic journals and conferences

Graduate Research Assistant
Jul 2016 – present
International Vaccine Access Center, Johns Hopkins University

- Searching database using MeSH terms and carrying out literature review for relevant publications to be included in the Pneumococcal Conjugate Vaccine (PCV) Impact systematic review study

- Abstracting data from published evidence including observational studies and clinical trials reporting changes in disease burden after PCV implementation to be included in a product assessment comprehensive review prepared for Gavi, the Vaccine Alliance to inform decision-making on product choice at the time of introduction of PCV to a national immunization program, and product switching after the product has been introduced
- Attending regular training on proper abstracting techniques

Teaching Assistant
Jul 2016-Aug 2016
Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health
- Provided guidance to students with minimal knowledge of epidemiology on the theories of epidemiology and its application

Pharmacy Manager
Egbeda Pharmacy, Lagos, Nigeria
Nov 2013 – Jul 2015
- General oversight, guidance and leadership of reporting pharmacists, interns and technicians
- Recruited, hired, trained and managed pharmacists and technicians
- Public health education, community organization and patient literacy
- Developed effective strategies for minimizing external/internal shrink
- Antibiotics stewardship awareness for staff and patients
- Sourcing, analysis and selection of cost-effective, low cost brands and generics for patients
- Educated pharmacists and technicians on reducing medication errors
- Provided general patient guidance, counselling and education
- Routinely evaluated customer feedback to identify strategies for improving customer satisfaction and quality of service

Pre-Registration Pharmacist
Beechcroft Pharmacy, Norwich, UK
Jul 2012 – Aug 2013
- Performed health checks and Medicines Use Review (MUR) under the supervision of the pharmacist, therefore acquiring consultation skills.
- Acted as a resource for other healthcare practitioners fostering good inter-professional relationship within the healthcare team
- Undertook the supervised consumption of methadone in the opioid cessation clinic
- Researched evidence based medicine
- Carried out an audit on amount medication waste generated in the pharmacy through patient returns
- Recommended protocols to manage drug inventory that were incorporated into the repeat prescription service offered at the pharmacy to reduce wastage
- Qualified to practice pharmacy in the UK

Student Research Assistant
School of Pharmacy, University of East Anglia, Norwich, UK
Oct 2011 – Feb 2013

- Participated in recruiting and consenting participants for pilot study on the impact of involvement of pharmacists in the primary care of patients with type 2 diabetes
- Involved in interviewing and collecting data from study participants.
- Carried out literature review for journal articles
- Participated in the design of new pharmaceutical care plans based on the outcome of the pilot study

Summer Placement Student
NHS Norfolk, Norwich, UK
Jul 2011 – Sep 2011

- Performed an audit on the hypnotic and benzodiazepine prescribing practices. This revealed the injudicious prescribing of these classes of medications to patients in the region, causing implementation of region wide guidelines on prescription of these medications
- Authored information packages that were sent out to pharmacies located in Norfolk regarding safe dispensing of methotrexate thereby raising awareness about careful dispensing practices

PROFESSIONAL DEVELOPMENT

Technical Skills: Competent in STATA, R, Microsoft Office packages (Word, Excel and PowerPoint)
Membership: Associate Member, Royal Pharmaceutical Society
2006-2013
Presentation at Scientific Meeting: Migration, Gender, and HIV Incidence in Rakai, Uganda. Themed discussion and poster session. Conference on Retroviruses and Opportunistic Infections (CROI), 2017
Awards

- Young Investigator Award recipient at CROI 2017
- Delta Omega Alpha Chapter poster competition overall winner award
- Masters Tuition Scholarship (2016-2017)
  -Academic scholarship awarded by Johns Hopkins Department of Epidemiology for partial tuition support